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STEWART'S BACTERIAL WILT ON SWEET CORN

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SUMMARY

1. Bacterial wilt or Stewart's Disease affects both sweet and field corn. Sweet corn is more seriously affected, and the earlier varieties are more susceptible than the later ones.

2. The disease is caused by a bacterium, *Aplanobacter Stewarti* (E. F. Smith) McCullock, which enters the plant from the seed or *through any broken tissue.*

3. The affected plants appear to be suffering from lack of water. This is actually what is happening, although the soil may be moist. Either the water-conducting vessels are clogged by the bacteria and hence the leaves cannot obtain sufficient water, or the substances formed by these bacteria kill the tissues of the leaves and thus produce the effect of wilting.

4. The bacteria are carried in the seed which may produce diseased plants. This seems to be the primary source of infection, or the means of introduction into an area. Probably the chief means of spread is insects, mainly flea beetles, which carry the bacteria from diseased to healthy plants. The possibility of infection through soil, manure or old stalks needs further confirmation.

5. The use of disease-free seed or disinfected seed does not insure a clean crop, once the wilt is established in a given neighborhood.

6. In Connecticut, where the disease is now quite wide spread, the use of resistant strains and varieties seems to be the chief solution.

In the Station trials, the first early varieties showing some resistance are Early Yellow Sensation, Spanish Gold and Burpee, but none in this season was immune.

In the midseason class, Whipple's is probably the best to grow. Gold Standard or Charlevoix (Ferry Morse Seed Co., Detroit, Michigan) gave good results in the 1933 trials. Whipple crosses bred by the Station are now available. They are quite resistant.

Of the later maturing varieties, Golden Cross Bantam is resistant and of good quality. In general, the later varieties are not so susceptible.

7. In the trials conducted by the Station, varieties developed in regions where there is no bacterial wilt have shown little or no resistance to the disease. On the other hand, varieties developed in regions where the disease is prevalent have, by natural selection, acquired some resistance to the disease and produced a more satisfactory crop here. Therefore it seems best to secure seed from areas where bacterial wilt is present. Such varieties will probably have some resistance to the disease.

8. By inoculation tests it is possible to isolate strains immune to bacterial wilt. The Station is making every effort to breed resistant strains suitable to Connecticut conditions and market demands.

STEWART'S DISEASE; CAUSE AND CONTROL

Stewart's disease or bacterial wilt affects both sweet and field corn, but causes most serious injury to sweet corn. It was first described from Long Island by F. C. Stewart of the Geneva Station, New York, in 1897. The next year E. F. Smith of the U. S. Department of Agriculture gave a specific name to the bacterial organism that causes the trouble—*Aplanobacter Stewarti.*

The trouble is characteristic when the young plants are about two feet high, although it often can be seen when they are only six inches

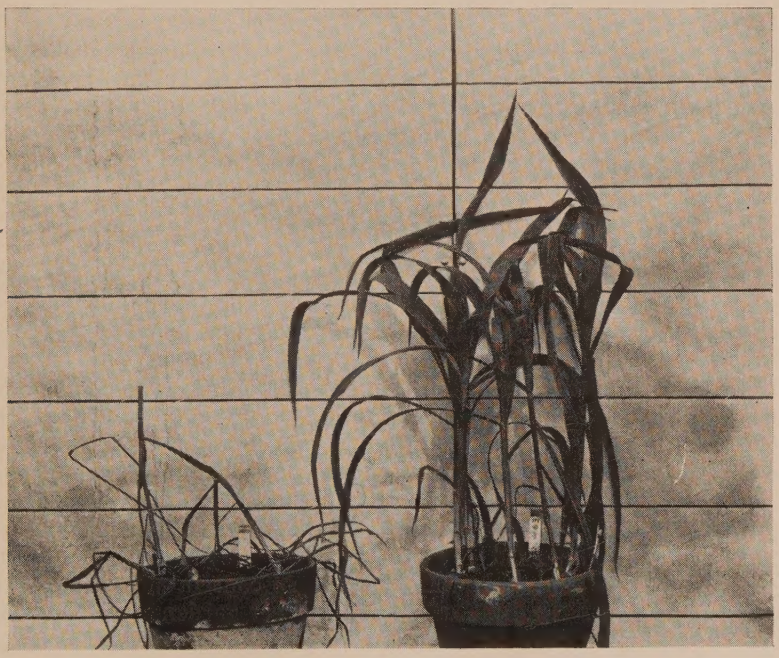

FIGURE 7. Inoculation trials with susceptible Whipple inbred. Pot at right not inoculated; pot at left inoculated with bacterial wilt.

high. The plants affected appear to be suffering from lack of water even though the soil may be moist. It shows first by a wilting of the older leaves and, if the injury is serious, the plants look almost as though frosted. Apparently the water-conducting vessels are clogged by the bacteria or else the substances formed by the bacteria kill the tissues of the leaves and this produces the effect of wilting. Usually there is no external evidence of any exudation or of a fruiting state of a fungus to indicate the cause of the trouble. Except for the wilted and dried up greenish leaves, the injury in younger plants is shown only by an internal reddish-brown discoloration or dead area at the base of the stem just above the hypocotyl that springs from the seed. If the stem

is cut lengthwise this discoloration is disclosed. If it is cut crosswise at this same place, one can see the yellowish (or occasionally whitish) ooze of bacteria issuing from the cut bundles.

When young plants are very badly affected they make little further growth and finally die. The young plants and even older ones very often rot off at the base so that they are easily pulled from the ground. Less seriously injured plants make a longer growth with more or less wilting and death of the leaves, but may fail to make tassels or ears. Some infected plants even reach maturity, but often with small or imperfect ears.

Since its discovery, Stewart's disease has been found in most of the states where sweet corn is grown commercially and, especially in the last few years, has proved a serious pest. Apparently the disease has not been as injurious in northern states as in those farther south, although the trouble was not uncommon in the Ontario province of Canada in 1932. In Maine it was not conspicuous in 1932, but it was found in several of the New England states farther south.

Occurrence in Connecticut

It is only recently that Stewart's disease has been a serious menace to corn in Connecticut. However, there is little doubt that we found this disease, on Golden Bantam late in July, 1919, although it was not definitely identified at the time. That year fields in Woodmont and Milford injured by the Fusarium root rot were being investigated. Notes made indicated the presence of bacteria, as well as Fusarium, in the rotted bases of the large stalks, and it was a question which was the primary cause of the injury. If examination had been made earlier, the cause of the trouble would have been more easily and definitely identified. In 1921, Rand and Cash, of the U. S. Department of Agriculture, definitely reported the trouble from this State. However, it was not until 1932 and 1933 that the trouble caused sudden and serious loss in Connecticut. In June of 1932 a market gardener of New Haven called our attention to a serious wilt and drying-up of his sweet corn. Examination showed the bacterial disease, and for the first time we obtained cultures of the organism for infection tests.

The fact that this disease varies in different years and places indicates that certain seasons are more favorable for its development and spread than others. If the germs carry over at all in the soil or in the manure, the type of winter may have something to do with the severity of the infections. The mild winters of 1931 and 1932 would have favored this. On this theory the severe cold period in late December, 1933 should decrease infection in the coming season, particularly if the snow mulch did not lessen the freezing effect in the soil.

A wet spring at the time of planting the corn may augment the seriousness of this trouble, especially if followed by hot, dry weather later on that favors loss of water by the plants. In 1932, for example, it was difficult in some cases to tell whether the injury to corn was drought injury or that caused by the wilt of Stewart's disease.

How the Disease is Spread

There seems to be no question that the bacteria are carried by the seed. Seed treatment has not proved so effective as it was once thought to be, so it is probably also true that the bacteria are carried more internally than externally.

Some think that seed infection is the only, or at least the chief, manner in which the bacteria carry over from year to year. There is reason to believe, however, that the germs may occasionally be carried in the soil, or in manure when it is applied in the spring and especially when it comes from animals, particularly hogs, that have been fed with corn or corn stalks that came from diseased plants. This statement is based on observation of a farm where the same seed was used for certain of the fields but where different fertilizers were used. Hog manure was used in some of the fields. In these fields the trouble was unusually conspicuous. In one field, however, where chemical fertilizers were used there was little trouble.

Rand and Cash (U. S. D. A. Tech. Bull. No. 362, May 1933) showed that insects, especially certain species of flea beetles, carry the germs from infected plants to healthy ones during the growing season. They believe that these insects are the chief source of the summer spread of the trouble, and insect inoculation would seem to be a good explanation of the difference, as shown by their experiments, between outbreaks in the District of Columbia and in Maine on plants grown from the same seed.

Infection Experiments

Greenhouse Experiment. The experimental work began in 1933. In early spring a greenhouse test was made on about 70 rows of seedlings, each row containing 20 seedlings of inbred corn from the same ear. Water containing pure cultures of the bacteria isolated from infected corn was sprayed on these seedlings. The plants were sprayed three times during a period of ten days. Usually before each spraying, half of the plants were pricked several times with a needle. The results of this experiment showed that of the 1,050 pricked plants 935, or 90 per cent became infected, while of the 918 unpricked plants only 55, or 6 per cent showed infection. This experiment seems to corroborate Rand and Cash's statement that injury by insects carrying the germs causes the spread of the disease.

Field Experiments. Field experiments on several phases of the problem were conducted at the Mount Carmel farm, with the following objectives: (a) to compare the effect of spraying the bacteria on pricked and unpricked plants, as in the greenhouse experiment; (b) to determine the value of seed disinfectants; (c) to test the possibility of infection from infected plant material in the soil; (d) to compare the susceptibility of ten standard varieties of sweet corn.

The plants were grown in six different rows. Each of the ten varieties was planted in the same order in each row, so that each row had about

1000 seeds. One row was kept as a check, but each of the other five was given a different treatment.

The results were recorded in two ways; first, the percentage of plants infected was determined (a slightly infected plant was counted the same as one killed when young); second, the effect of infection was determined by assigning different percentages to each plant according to its condition, as follows: a perfectly healthy plant was assigned 0 per cent; a slightly infected one 30 per cent; a moderately infected one 50 per cent; a badly infected one 80 per cent; a dead or nearly dead one 100 per cent. The determinations were made by both the external

FIGURE 8. Inoculation trials in greenhouse. Spanish Gold inbred. Plants at left sprayed with bacteria, not pricked; plants at right sprayed with bacteria, pricked with needle before spraying.

and internal appearance of each plant. The examination was made in July after many of the plants had made their full growth but before they had tasseled. While these two types of measurement showed the same general results, the percentage of the number of plants affected was of course larger in each case than the percentage showing the degree of injury.

The treatments and the results of the several experiments are as follows:

(a) Half of the plants of each variety in one row were pricked before they were sprayed with water containing the bacteria. The effect of pricking the leaves was not as marked as in the greenhouse experi-

ment. The pricked plants showed 40 per cent injury, as against 38 per cent for the unpricked—not a significant difference. It is fair to assume that this experiment was upset by some other factor—probably the transmission of the trouble to all the plants by insect inoculation, such as Rand and Cash describe.

(b) Three of the rows were planted with seed which had been treated with a disinfectant. The seed in each of these rows was treated with a different disinfectant, as follows: (1) Seed treated with corrosive sublimate, 1 to 1000, by soaking for 15 minutes; (2) seed dusted with Semesan; (3) seed treated with formalin, 2 per cent, by soaking for 15 minutes.

The percentage, first, of the total number of plants infected and, second, the percentage showing the degree of injury on the various rows is given in the following table:

	Seed treated with corrosive sublimate	Seed treated with Semesan	Seed treated with formalin	Check—no treatment
	%	%	%	%
1. Total number of plants infected	52	61	67	64
2. Degree of injury	22	27	33	29

There was, as the table shows, very little difference in the results from these treatments. The amount of injury in the corrosive sublimate row was least, 22 per cent, as compared with the other rows, Semesan, 27 per cent, control row, 29 per cent, and formalin, 33 per cent. There was some injury to the row treated with formalin from the formalin itself, which may have caused part of the injury that was laid to the wilt. This difference in the relative amount of injury was not sufficient to recommend seed treatment as an effective measure of control. If, however, seed treatment is used as an extra precautionary measure, the corrosive sublimate treatment would seem to be the best.

(c) In a fifth row, ground and dried infected plant tissues were planted with the seed. The infected material had been kept indoors during the winter. Moreover, so little was used that this row was not expected to show any great difference from the other rows. It showed slightly less injury, 26 per cent, than the check row, 29 per cent. All of the other rows except that in which the seed had been treated with corrosive sublimate showed more injury. This result, as well as other observations elsewhere, indicates that corn will not escape infection when planted in land not recently in corn.

(d) As to the relative susceptibility of the ten varieties, this experiment showed that, in the order of their maturity, the earlier varieties were more seriously affected than the later varieties. This result tallies with general observations made in the fields over the State. Yet certain varieties stood up better than others. The strain that stood up best in this test was Golden Cross Bantam, which showed only 5 per

cent injury; next was Whipple's Yellow, 11 per cent injury; Spanish Gold, 13 per cent; and Red Green, 14 per cent. These varieties also showed the smallest percentages as to the number of plants infected. Golden Gem was the least resistant of the varieties tried. It showed 64 per cent injury, and 95 per cent of the plants were affected.

Apparently the most effective method of combatting Stewart's disease is to plant only those strains which are least affected by it. The results of plant breeding experiments and additional information on resistant strains are given in the next section.

One grower, however, successfully fought the infection by planting his seed rather thickly in the rows and then hoeing out plants as soon as they showed symptoms of the trouble. In this way he got a fair stand of plants that came to maturity. Of course, in case the disease does not appear, this method entails unnecessary work in thinning out the stands.

BREEDING RESISTANT STRAINS

With a view to finding varieties resistant to bacterial wilt, 81 samples of early yellow and white sweet corn were tested in 1933 on the Station's farm in Mount Carmel. This list included most of the standard varieties grown in this section as well as new varieties or crosses recently introduced. In most cases only one row of each sample was grown. The rows were 21 feet long. The results based on this area are subject to considerable chance variation, and different samples of the same variety might show large deviations. However, important differences between varieties should be apparent and promising varieties will be tested more thoroughly another year.

Before bacterial wilt became widespread in Connecticut there were several varieties that met the need of growers who desired a first early sweet corn. Probably the two most widely grown commercially were Golden Early Market and Golden Sunshine. Both of these have proved to be highly susceptible to bacterial wilt and this now makes their use questionable. Sunshine is a little more resistant than Golden Early Market. In our trials we had Golden Early Market from five seedsmen. No lot produced more than 2000 ears per acre. One lot of Sunshine yielded twice this amount, but even so, the crop was unprofitable.

Judging by the prevalence of the disease on susceptible plants, it seems likely that all plants were inoculated with the disease. This is plausible in view of the fact that the disease is spread by insects, mainly flea beetles. The plants that escaped the disease were almost certainly resistant. It is interesting to note that the varieties found most susceptible had been produced in regions where wilt was unknown and hence had no opportunity to develop resistance. Seed of varieties such as Golden Gem

and Golden Early Market had been grown on the Pacific coast where wilt has not occurred. Therefore, the seed was free of infection, yet these varieties were the most seriously affected with the disease. Another experiment showing that plants from disease-free seed may become infected was conducted last summer. In trying to secure early inbreds we decided to grow again some of Lord's Early Yellow. The only seed

FIGURE 9. Susceptible strain of Whipple in center. Indiana 39 and resistant Whipple inbreds on either side.

we had was produced in 1929 when there was no wilt. Hence the seed was free of disease. Of 20 plants grown, 16 were badly diseased at the time the notes were taken and no ears were obtained from the other four plants. In other words, this lot was between 75 and 100 per cent infected.

On the whole, varieties developed where wilt has been prevalent are more resistant to the disease. It therefore seems wiser to obtain seed from regions where there has been wilt for a long time. The chances are better of getting a resistant variety.

Varieties Partially Resistant

In our trials there were a few first early varieties that showed some resistance to bacterial wilt. Both Early Yellow Sensation and Early Golden produced sizeable ears and gave a fair yield—7000 ears per

acre. Spanish Gold produced the same amount of marketable ears, and was five to seven days earlier than the two varieties previously mentioned, but the ears were somewhat smaller. For the home garden, or for the gardener who has a market for the first early corn with medium-sized ears, Spanish Gold is still to be considered. For the general market gardener, the ears of Spanish Gold are probably too small. Burpee produced 5,000 ears per acre and was as early as Golden Early Market. The ears are about the same size as those of Golden Early Market.

In the midseason class, Whipple's Early Yellow is probably the best variety to grow. It is fairly resistant to the disease and produces a good yield of large marketable ears (average of five samples more than 7000 marketable ears to the acre). In this same season, Charlevoix or Gold Standard (Ferry-Morse Seed Co., Detroit, Michigan) was exceptionally free from the disease (94 per cent healthy plants) and gave a good yield of 8000 marketable ears to the acre. The ears are a little smaller than those of Whipple.

Eight-rowed Golden Bantam

The varieties of Golden Bantam differed considerably. Some produced no marketable ears at all. Two samples, Reeves' Golden Bantam from K. C. Livermore, Honeoye Fall, N. Y., and Golden Bantam from Grand Junction Seed Company, Grand Junction, Colo., gave good yields of 9,000 and 11,000 marketable ears respectively. These samples seemed true Golden Bantams, mostly eight-rowed, with an occasional 10-rowed ear. Another sample, Stevens' Golden Bantam from Gunson & Co., Rochester, N. Y., gave a remarkable yield of 14,000 ears, but the ears varied in row number of eight to sixteen and would probably not pass for a true Golden Bantam. The quality of these samples was not tested. Three samples of Barden's Wonder Bantam were tested. They all produced from 10,000 to 13,000 marketable ears which had good flavor and were judged quite tender. Some persons who tested them judged Wonder Bantam equal to Golden Cross Bantam in quality and flavor. Wonder Bantam had predominately eight rows, although in two samples there was an occasional ear with ten rows. Where an eight-rowed Bantam is desired, these varieties are well worth considering. We do not know the quality of the canned product.

Promising Hybrids

Golden Cross Bantam is well known for its high quality and resistance to bacterial wilt. It produced the largest number of marketable ears, 15,000, of all varieties or crosses tested. It is a little late for the first early or midseason crop and some new hybrids have been developed to meet the need of the earlier growers. Tendergold is about in the Whipple season or perhaps a little earlier. It has good quality and some resistance to bacterial wilt, although it is not immune. It pro-

duced 7,000 and 8,000 marketable ears to the acre. This cross is thought to be a top cross of Sunshine by Indiana 39.

One of our own top crosses, Spanish Gold by 482-2 (a Whipple inbred) was just as early as Golden Early Market, produced one large ear to the stalk, and was almost immune to bacterial wilt. It produced 94 per cent of healthy plants in comparison with 0 to 13 per cent for Golden Early Market and gave a yield of 9,000 marketable ears per

FIGURE 10. Whipple Cross grown at Windsor and Mount Carmel showed no injury from bacterial wilt.

acre. The highest yield of Golden Early Market was 2,000. There will be seed of this new top cross for distribution in the spring of 1935.

Another top cross that gave a better yield, although a little later, was Spanish Gold by Indiana 39. It produced an average of 10,000 ears to the acre. It is in the same season as Early Yellow Sensation and Early Golden. There is a limited supply of seed for distribution in 1934 by the Associated Seed Growers, New Haven, Conn.

An Inbred as a Variety

Indiana 39, an inbred produced by the Indiana Station and used as one of the parents of Golden Cross Bantam, has been put out as a commercial variety under the name of Purdue Bantam. It is an unusual inbred which retained considerable vigor upon selfing. It gave a good yield, 11,000, of medium-sized ears. This variety was not tested for quality.

Whipple Cross

A large number of crosses of inbred strains of Whipple's Yellow sweet corn are being tested for adaptability and for resistance to bacterial wilt. Some of these have been entirely free from disease symptoms both at Mount Carmel and at Windsor. At the same time they have produced large well-filled ears on practically every stalk, and these all ripened very nearly at the same time.

There will be small amounts of seed of first generation Whipple crosses and Whipple top crosses, for growing in 1934. These will be distributed by the following seed companies: Comstock, Ferre Co., Wethersfield, Conn.; F. S. Platt Seed Co., New Haven, Conn.; and F. H. Woodruff and Sons, Milford, Conn.

First Early Variety

There is a particular need for a first early variety resistant to bacterial wilt. We have already begun work on such a variety. Crosses were made last year which in a short time should give a first early variety that has a large ear and is highly resistant to the disease. Three generations of corn were grown in 1933, two in the greenhouse and one in the field. By this method of growing three generations in a season, we can materially reduce the time required to produce a new variety. By inoculation tests it was possible to isolate resistant inbred strains and these were used in crossing to get resistance for the new variety. Some inbred strains when pricked and inoculated, as described on page 29 were 100 per cent susceptible, and others were nearly 100 per cent immune. These inoculation tests give promise of isolating strains resistant to the disease. By obtaining resistant inbreds we can produce new types of corn that will be immune or highly resistant to bacterial wilt. This seems at present to be the most feasible method of controlling the disease.